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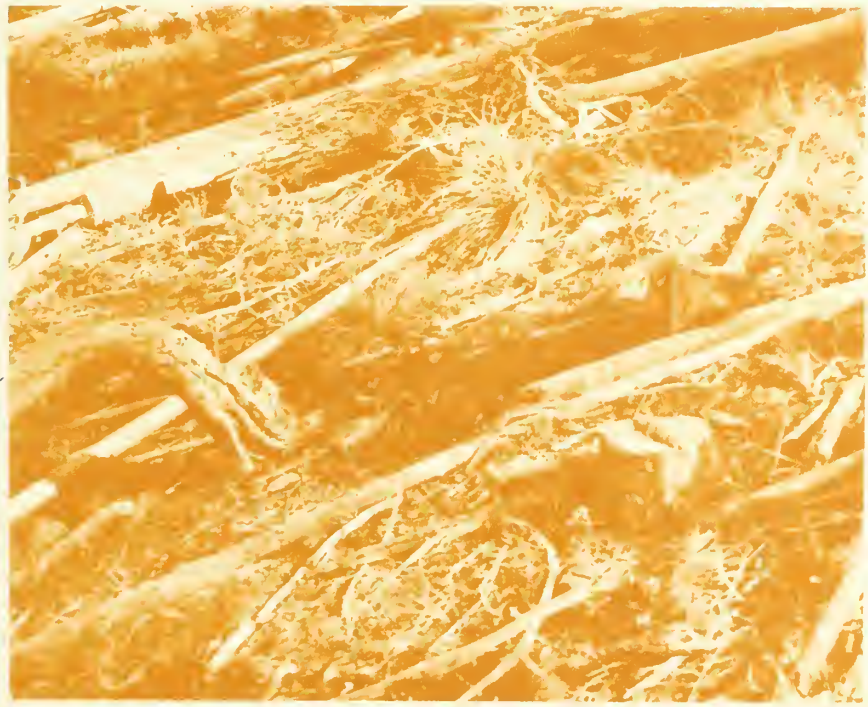

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CONTENTS

	Page
INTRODUCTION	1
CHIP QUANTITY AND QUALITY	1
Sampling and Processing	1
Results and Discussion	3
PULPING DEAD LODGEPOLE PINE	8
Sample Collection and Pulping	8
Results and Discussion	10
CONCLUSIONS	10
PUBLICATIONS CITED	11

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RESEARCH SUMMARY

The vast quantity of dead down and standing timber in the Rocky Mountains is a potential resource for the pulp and paper industry. Pulpwood bolts of dead Engelmann spruce, Douglas-fir, western larch, and lodgepole pine were experimentally chipped and evaluated as pulp material. Samples from dead bolts and green bolts indicated that the dead wood was sound (specific gravities were essentially the same) and that the dead tree bolts had a much lower percent moisture content than the green bolts. As a result of the lower moisture content, 14 to 30 percent more power was required to chip the dead trees than the green trees. Also, chipping the dead wood produced a slightly larger percentage of fines than the chipping of green wood. No problems were encountered in separating the bark from the wood chips. Test runs made with dead lodgepole pine chips indicated that the pulp should be suitable for a variety of paper and board products.

INTRODUCTION

The Rocky Mountain region contains vast quantities of dead down and standing timber that, after many years of exposure to the elements, has suffered little deterioration. The exact quantity of dead timber available is unknown, but estimates place the amount at approximately 3.5 billion cubic feet and this amount is increasing annually as insects and disease continue to take their toll of green timber.

Many of the dead trees are removed from the sale area at the time of harvesting the green timber, but the bulk of this material is left on the area and becomes a part of the logging residue. More intensive use of dead trees would enhance the raw material base of the region's wood-using industry, facilitate management practices on logged-over areas, and help decrease the cost of postharvest cleanup.

One possible method of utilizing dead trees in this region is to chip the wood either in the forest or at the mill, for manufacturing into paper. However, the paper-making industry needs additional information regarding the processing and quality of the resulting chips.

This paper reports the results of two investigations: (1) characteristics of chips from dead down and standing trees, and (2) the pulping characteristics of dead lodgepole pine trees. The studies are discussed separately.

CHIP QUANTITY AND QUALITY

Objectives of this part of the study were: (1) to compare quantities and sizes of chips obtained from green trees and dead trees of the same species; (2) to compare horsepower required to chip various sample bolts; and (3) to determine whether current technology would remove bark from chips produced from dead trees.

Sampling and Processing

Samples of dead down, dead standing, and green trees were selected in a single drainage in western Montana. Each sample consisted of about six 5-foot-long bolts with a maximum diameter of 7 inches, weighing in excess of 100 pounds. The bolts were of sound wood with no obvious decay.

Four species, lodgepole pine, Engelmann spruce, Douglas-fir, and western larch, were included in the sample. These species represent a range in average specific gravity from 0.33 (Engelmann spruce) to 0.48 (western larch) (USDA Forest Service 1974).

At the time the bolts were collected, disks, approximately 1 inch thick, were cut from the tree stem immediately adjacent to the bolt ends. These disks were identified as to tree and bolt and were used for determining specific gravity and moisture content of the sapwood and heartwood.

A total of 60 bolts, 15 of each species, 5 each from dead down, dead standing, and green trees, were individually wrapped in polyethylene to prevent changes in moisture content and to capture bark that sloughed during shipping and handling. The bolts were shipped to the Forest Engineering Laboratory at Houghton, Michigan, for processing.

Just prior to chipping, the samples were unwrapped and any loose bark weighed. All material was chipped by a 48-inch, 3-knife Morbark Chip-pak chipper with the chipper knives being ground just prior to testing. During chipping, the input power was measured by a Hall-effect, three-phase wattmeter transducer (Papworth and Johnson (1968). The output from this transducer was displayed on a single channel of a Sanborn recorder. The total area under the recorded power curve was measured with a compensating polar planimeter to determine total energy consumed during chipping.

Following chipping, representative samples were uniformly mixed and classified to size with a Sweco round-hole screen classifier (fig. 1). Each size class was subsequently weighed and sampled, with the samples being manually segregated to determine percent bark in each size. All analyses were based on dry weights.

Figure 1.--Sweco round-hole classifier for classifying wood chips according to size.

The bark removal methods used were not independent, separate systems, but were variations of one system. The system components used are briefly summarized and coded for reference:

Compression debarking (C).--A processing treatment in which the bark/wood chip mass is passed between two opposed, hydraulically loaded, steel compression rolls placed 0.020 inch apart. Bark generally adheres to the rolls more readily than wood and is scraped from the rolls 180° from point of compression. Screening the chip output removes much of the bark that does not adhere to the rolls, but that has been fragmented by the roll nip action (Arola and Erickson 1973).

Ball milling (B).--Chip output is passed through a specially designed ball mill to further break up any bark not removed by compression debarking for subsequent screening (Mattson 1974).

Steaming (S).--Prior to compression debarking, the bark/chip mass is presteamed for 5 minutes at 30 psi to enhance bark removal.

Air flotation (A).--A processing treatment that removes up to 60 percent of the input material as clean wood chips, leaving the remainder for compression debarking. This process segregates particles having distinct differences in terminal settling velocities due to density, shape, or size (Sturos and Erickson 1974).

To establish final output products after processing, two final screening methods were examined: (1) to include in the output the 3/16-inch size chips which are generally high in bark content but increase wood recovery, and (2) to exclude the 3/16-inch size chips which generally increase bark removal but decrease wood recovery. The latter method is on the assumption that the rejected material will be utilized for other products or for fuel. Although bark removal from green chips was not intended to be part of the study, results are included to provide additional information on western species (Arola and Host 1976; Hillstrom 1974).

Results and Discussion

Specific Gravity and Moisture Content

Average specific gravity and moisture content are shown in table 1. In general, the specific gravity values approximate the published values for the different species and, as expected, there were only small differences between the values for the dead and green trees. The differences between the sapwood and heartwood determinations can, perhaps, be attributed to the extractive content present in the heartwood.

The moisture content of the sapwood of the green bolts was much greater than the moisture content of the heartwood. This agrees with published information (USDA, Forest Service 1974). For the dead trees, the sapwood had a lower moisture content than the heartwood. This, too, is as expected because the sapwood is more exposed than the heartwood and hence would dry more rapidly. The bolts from the green trees had a much higher moisture content in both sapwood and heartwood than the bolts from the dead trees. The dead down trees had slightly higher moisture content than the dead standing trees. Undoubtedly, the down trees absorbed some moisture from the ground and were, in addition, shaded and protected by herbaceous plants from the direct influence of the elements.

Horsepower Requirements

Horsepower requirements for chipping dead and green wood of the four species are listed in table 2.

Table 1.--*Average percent moisture content and specific gravity of samples taken from the ends of the sample material*[1]

Species	Condition	Average percent moisture content: Sapwood	Average percent moisture content: Heartwood	Average specific gravity[2]: Sapwood	Average specific gravity[2]: Heartwood
Lodgepole pine	Green	114	50	0.37	0.38
	Dead standing	16	18	.42	.42
	Dead down	21	27	.34	.35
Douglas-fir	Green	112	29	.41	.49
	Dead standing	14	15	.40	.43
	Dead down	18	26	.34	.37
Engelmann spruce	Green	97	40	.33	.37
	Dead standing	19	27	.36	.37
	Dead down	22	28	.37	.41
Western larch	Green	104	41	.42	.41
	Dead standing	13	13	.44	.42
	Dead down	21	29	.37	.42

[1] Each value is the average of at least four determinations.
[2] Based on green volume and ovendry weight.

Table 2.--*Horsepower requirements for chipping three types of wood of four different species*

Species	Hp-min per ft^3[1]: Dead down	Hp-min per ft^3[1]: Dead standing	Hp-min per ft^3[1]: Green	Percent increase: $\frac{\text{Ave. dead}^2 - \text{green}}{\text{green}} \times 100$
Lodgepole pine	[3]285.17 (19.3)	272.00 (10.4)	214.54 (8.7)	29.85
Douglas-fir	252.38 (19.3)	238.43 (25.4)	214.86 (7.6)	14.22
Engelmann spruce	275.20 (14.1)	220.01 (12.3)	189.82 (3.5)	30.44
Western larch	205.67 (23.0)	237.18 (9.6)	186.92 (12.3)	18.46

[1] To convert $\frac{\text{hp-min}}{\text{ft}^3}$ to $\frac{\text{hp-h}}{\text{cord}}$ multiply by 0.022222.

To convert $\frac{\text{hp-min}}{\text{ft}^3}$ to $\frac{\text{Joules}}{\text{m}^3}$ multiply by 0.026345.

[2] Includes both dead down and standing
[3] Mean with std. dev. in parentheses.

The total energy required to chip the various types of wood was analyzed using the analysis of variance method. The results of this analysis showed a significant difference, at the 95 percent confidence level, in the energy required to chip dead wood as opposed to green wood for all species. However, there was little difference when comparing energy required to chip dead standing with dead down wood. Lodgepole pine (dead down) required the greatest amount of energy at 285.2 horsepower minutes per cubic foot (hp-min/ft^3) compared to green lodgepole at 214.5 hp-min/ft^3. The largest differences occurred with Engelmann spruce and lodgepole pine where approximately a 30 percent increase in power was required to chip dead wood compared to green wood.

The differences in power requirements can probably be attributed to the differences in moisture content. Apparently the moisture in wood acts somewhat like a lubricant and reduces the energy required to chip or saw green wood (Quelch 1964).

Chip Yield and Characteristics

Chip size.--Differences in chip size classes within species and between conditions was not as marked as expected (fig. 2, 3, 4, and 5), with only a slight increase in fines occurring between green and dead. Overall chip quality was good, with more than 75 percent of the chips falling in the -1-1/8 to +3/8 category in all cases.

Bark removal.--Many of the dead wood samples either did not contain any bark before shipping, or lost much of their bark in shipping and handling. Therefore, the majority of chipped samples did not contain enough residual bark to require processing.

The data for these species were:

	Percent bark after chipping
Douglas-fir (dead standing)	0.35
Douglas-fir (dead down)	.23
Lodgepole pine (dead standing)	2.46
Lodgepole pine (dead down)	.33
Engelmann spruce (dead down)	.19
Western larch (dead standing)	1.58

Of the material tested, with the exception of Douglas-fir, excluding the 3/16-inch chips from the output increased bark removal but decreased the amount of wood fiber recovered (table 3). Douglas-fir bark, because of its physical nature, is not easily fragmented by the roll nip action, therefore introduces larger bark particles into the final output. Consequently, rejection of the 3/16-inch size chips, the most bark-free chip size for Douglas-fir, increased bark content and decreased the percentage of wood in the final output. In contrast, excluding the 3/16-inch chips from the western larch (dead down) output reduced final bark percentages by over one-half, with little effect on wood recovery. In all cases except for Douglas-fir, with selection of the proper output, residual bark is less than 4 percent, with at least 95 percent of the original wood fiber recovered.

Although we had trouble debarking green Douglas-fir chips, a pressurized bench top device (Plahutnik 1973) showed promise for segregating clean chips from barky chips. When sufficient pressure is applied to a floating chip, water is forced into the intercellular spaces, causing the chips to sink. If the wood and bark behave differently under pressure, segregation occurs.

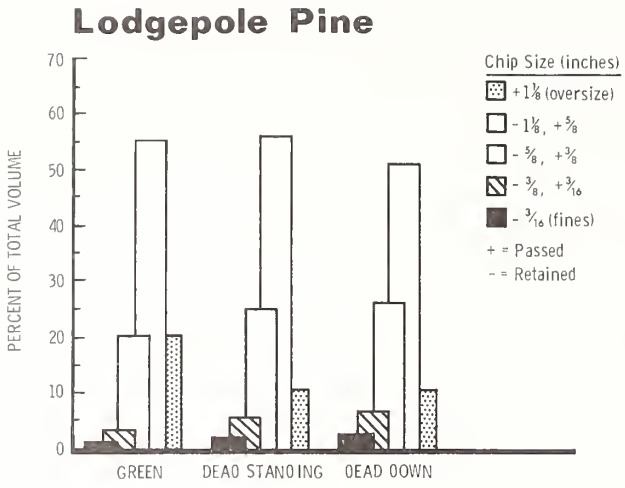

Figure 2.--Distribution of green, dead standing, and dead down lodgepole pine pulp chips according to size.

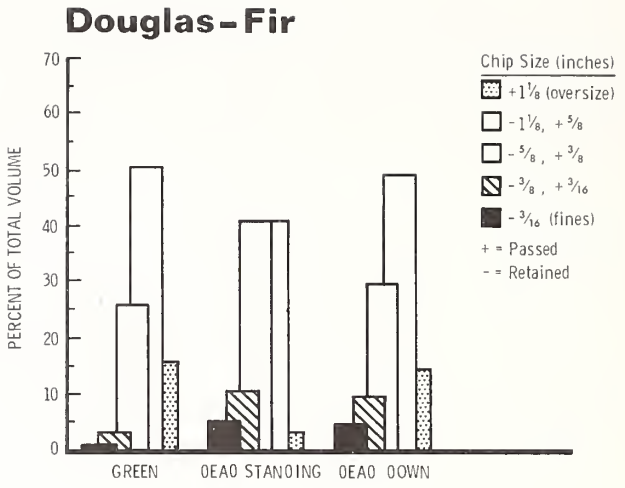

Figure 3.--Distribution of green, dead standing, and dead down Douglas-fir pulp chips according to size.

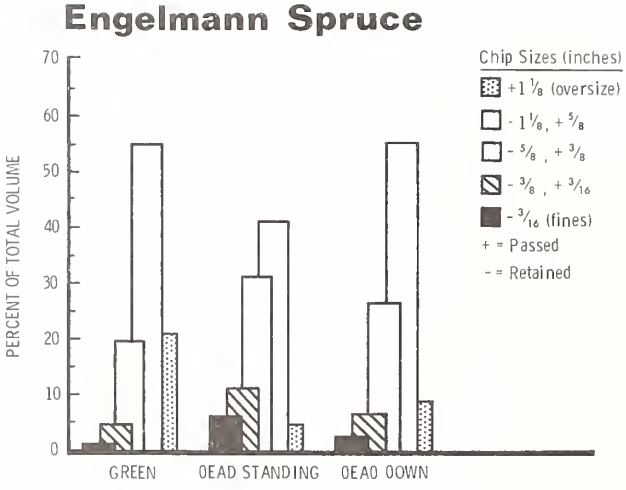

Figure 4.--Distribution of green, dead standing, and dead down Engelmann spruce pulp chips according to size.

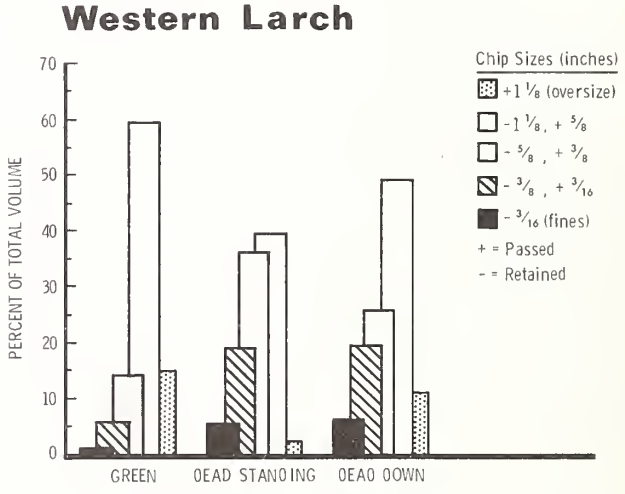

Figure 5.--Distribution of green, dead standing, and dead down western larch pulp chips according to size.

Table 3.--*Results of bark-chip separation methods with different species and types of wood*

Species	Condition	Bark removal process[1]	Input bark	Output including 3/16 chips: Output bark	Bark removed	Wood recovered	Output excluding 3/16 chips: Output bark	Bark removed	Wood recovered
				Percent[2]					
Lodgepole pine	Green	SCB	6.8	1.0	87.2	95.5	0.3	96.7	75.1
Douglas-fir	Green	SCB	15.7	8.8	54.6	97.5	9.8	64.8	69.9
Engelmann spruce	Green	AC	13.4	4.1	72.8	98.8	3.5	77.4	95.6
Engelmann spruce	Dead standing	ASC	12.3	1.9	86.7	95.5	1.6	89.8	89.6
Western larch	Green	SCB	14.3	3.9	76.5	95.2	2.3	89.8	73.6
Western larch	Dead down	ACB	8.6	7.2	18.8	99.1	3.5	45.3	95.3

[1]Bark-chip separation methods coded as follows: S - steaming; C - compression; B - ball milling; and A - air flotation.
[2]Based on sample weights.

PULPING DEAD LODGEPOLE PINE

Sample Collection and Pulping

In the second part of the study, a sample of lodgepole pine was collected and shipped to the Forest Products Laboratory at Madison, Wisconsin, for pulping tests. The sample material consisted of 15 bolts, 4 feet long, obtained from insect-killed trees near Missoula, Montana. The trees had been dead for at least 7 years, with no decay and little bark.

At the laboratory, the bolts were chipped and the chips were subjected to two pulp digestions. After the digestions, the pulp and few sample handsheets prepared from the pulp were evaluated according to Technical Association of Pulp and Paper Industry (TAPPI) Standards (table 4).

Table 4.--*Properties of kraft pulp made from dead lodgepole pine (source of tests and terms--Technical Assoc. Pulp and Paper Industry)*

Test number	Digestion number	Test	Freeness 600	500	400	300
25356	5904-X	Burst factor	102.0	111.5	115.5	117.5
Yield = 52.8%		Tear factor	108.0	97.5	90.0	89.5
Kappa = 78.3		Breaking length - M	13,850	14,600	14,900	15,000
		Density - G/cc	0.63	0.68	0.71	0.74
		Beating Time - Min	44	62	75	85
25357	5903-X	Burst factor	99.0	109.0	114.0	117.0
Yield = 46.7%		Tear factor	117.5	95.0	90.0	88.0
Kappa = 34.6		Breaking length - M	13,900	14,850	15,350	15,600
		Density - G/cc	0.68	0.73	0.75	0.76
		Beating Time - Min	19	30	39	47
25357-A	5903-X	Burst factor	96.0	107.0	112.0	113.0
	Bleached 6792	Tear factor	118.0	101.0	94.5	91.0
	CEDED	Breaking length - M	12,550	13,850	14,500	14,800
		Density - G/cc	0.72	0.76	0.77	0.79
		Beating Time - Min	10	18	25	30

The pulping and bleaching characteristics of the dead lodgepole pine were quite satisfactory. The yield for the bleached pulp was 46.7 percent and for the linerboard 52.8 percent (table 5). The pulp properties, also, were exceptionally good and about the same as that obtained from green wood of this species (typical of the species having low density wood and slender fibers). The quality of these properties is shown by high burst and tensile strength and low tearing resistance of the handsheets. Apparently the long exposure of the trees had little effect on quality of pulp.

Table 5.--*Cooking conditions and results of two digestions made with dead lodgepole pine pulp chips (source of tests and terms--Technical Assoc. Pulp and Paper Industry)*

Digestion 5903-X (For bleaching)	17.51% active alkali, 25.0% sulfidity L/W = 4/1 90 min 80-170°, 90 min at 170°C.
	Spent liquor 8.4 g/l Na_2S (Na_2O) 6.2 g/l NaOH (Na_2O)
	Yield Total 46.7% Scr. 0.9% (0.012 inch)
	Kappa No. = 34.6
	Bleaching: C - Cl_2 - 7% Brightness = 89.2% E - NaOH - 2% D - ClO_2 - 0.76% E - NaOH - 1% D - ClO_2 - 0.38%
Digestion 5904-X (For linerboard)	15.0% active alkali, 25.0% sulfidity L/W = 4/1 90 min 80-170°, 45 min at 170° C.
	Spent liquor 7.0 g/l Na_2S (Na_2O) 4.3 g/l NaOH (Na_2O)
	Yield Total 52.8% Fiberized in 8-inch Bauer
	Kappa No. = 78.3

Results and Discussion

The results of this limited study indicated that, as in the previous study, chipping dead wood produced a higher percentage of fines than chipping green wood. Some of these fines might be salvaged, if suitable digestion equipment is available. Chip yield was as follows:

	Kg(wet)	*Pct*
Bolts	81.90	
Fines (passed through 1/4-inch screen)	6.60	8
Oversize (retained on 1 1/4-inch screen)	1.58	2
Accepts	73.72	90

CONCLUSIONS

Studies indicate that standing and down dead Engelmann spruce, Douglas-fir, western larch, and lodgepole pine trees can be chipped satisfactorily. Because of the lower moisture content in the dead trees a significantly greater amount of power was required to chip the dead than the green trees. Depending on the species, this increased power varied from approximately 14 to 30 percent. The dryness of the wood also affected the percent of fines (unusable wood chips) produced. Chipping dead trees produced a slightly larger percentage of fines than chipping green trees.

Separating bark from wood chips should present no major difficulty. Sample bolts from the dead trees had lost most of their bark during handling and shipping. Similar bolts for a commercial operation would probably arrive in the same condition with large amounts of the bark either sloughed or knocked off.

No problems were encountered in pulping dead lodgepole pine. Experimental digestions and evaluation of the pulp and handsheets indicated that the material could be used for the manufacture of both bleached and unbleached pulps suitable for a variety of paper and board products. The quality difference between these pulps and pulps made from green lodgepole pine wood was insignificant.

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Evaluations of dead trees of five Rocky Mountain species for raw material for pulp and paper indicate that no more horsepower was required to chip dead trees than green trees. Dead trees produced slightly greater pulp yields and were easier than the green trees. No problems were encountered in removing the bark from the wood chips or in pulping the dead lodgepole pine chips.

KEYWORDS: chipping, dead trees, chip barkability, horsepower required to chip, pulping, dead lodgepole pine

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